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CHARACTERISTICS OF LEAF STRUCTURAL TRAITS AND THEIR CORRELATIONS IN OAK FOREST, TURKEY

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Abstract

Leaf fresh and dry weight, dry matter content, leaf surface area and specific leaf area of plant species in a Turkey oak forest were investigated and correlated. The study was carried out in two different parts of the forest to examine effects of lumbering and harvesting on leaf traits. Plant species were grouped into four growth forms as trees, shrubs, grasses and herbs. Only dry matter content of leaves differed significantly among growth forms in both plots. It was found that there were significant correlations among leaf traits of growth forms.

Introduction

Leaves are one of the vital organs which perform a major part of photosynthetic activity of plants. Leaf shape and size, anatomical structure, nutrient content and water content differ among plant species and individuals. Leaf traits such as specific leaf area (SLA), leaf dry matter content (LDMC), leaf dry weight, leaf surface area etc. provide a useful conceptual link between processes at short-term leaf scales and long-term whole plant and stand-level scales and manage plant growth together (Luo *et al.* 2005).

Specific leaf area which is a measure of leaf surface area per unit mass, is a fundamental leaf trait characterizing plant adaptation to environmental conditions. It was determined that SLA varies considerably between species, individuals and within plant canopies (Garnier *et al.* 1997, Knops and Reinhart 2000, Liu *et al.* 2008) and also varies more than ten-fold among species growing interspersed in the same habitat (Westoby *et al.* 2000, Li *et al.* 2005). LDMC is an important leaf trait and increasingly used as an indicator of a plant species resource use strategy (Grime 1974, Wilson *et al.* 1999), i.e. its position in a fundamental trade-off between a rapid assimilation and growth at one extreme, and efficient conservation of resources within well-protected tissues at the other (Vaieretti *et al.* 2007).

Among the plant traits scientists have looked into, leaf traits are often considered the principal traits with regards to plant resource use, biomass and ecosystem functioning and adaptation to environment (Liu *et al.* 2008). There are several studies on variations of leaf traits at different environmental conditions (Knops and Reinhart 2000, Jullien *et al.* 2009) on relationships among plant traits (Luo *et al.* 2005, Vile 2005, Liu *et al.* 2008) and determining leaf traits (Li *et al.* 2005, White and Scott 2006).

It was aimed to explore the characteristics of leaf structural traits of plant species in the Turkey oak forest. Turkey oak forests widely spread in Anatolia and are dominant in northern Turkey. It was tried to explain which leaf trait was more sensitive for forest ecosystems. For this purpose, fresh weight, dry weight, LDMC, leaf area and SLA of plant species were measured and calculated. Focus was also given to examine how leaf traits range among growth forms and whether leaf traits of plant species vary with lumbering and harvesting or not.

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Materials and Methods

The study was carried out in a *Quercus cerris* L. var. *cerris* forest (Turkey oak) in the Kurupelit region, Samsun, northern Turkey (41°21.982'N, 36°11.152'E). Mediterranean climate is seen at the study area. Annual mean temperature was 14.2°C, maximum temperature is 37.4 °C, minimum temperature is –7.0°C, total annual precipitation was 668.9 mm^3. Mean altitude of the study area from sea level was 250 - 300 m. Soil type of the study area was grey-brown and podzolic. Because of the precipitation due to rainfall, the color of the upper horizon (A) and the deep layers of these soils were grey and brown, respectively (Özen and Kılınç 1988). *Quercus petraea* (Mattuschka) Liebl. subsp. *iberica* (Steven ex Bieb.) Krassiln, *Q. cerris* L.var. *cerris* L. and *Carpinus orientalis* Mill. were dominant species at the tree layer and *Crataegus monogyna* Jacq. subsp. *monogyna* Jacq., *Ligustrum vulgare* L., *Smilax excelsa* L. and *Clematis vitalba* L. were dominant species at the shrub layer. Aditionally, there were some Mediterranean species such as *Phillyrea latifolia* L., *Ruscus aculeatus* L. var. *aculeatus* L. (Özen and Kılınç 1988). There were various plant species in the herbaceous layer.

Two permanent plots, namely plot 1 and plot 2 were chosen to examine the effects of lumbering and harvesting. Plot 1 (20 ha) was selected from the site disturbed by lumbering of some of the trees and harvesting all plants of herb and shrub levels of the woodland two years ago and plot 2 was unimpaired. Plots were chosen on the basis of canopy cover, and tree density. Plot 2 had 65% canopy cover as against 45% in plot 1. Field surveys were carried out between March and August in 2005 in growing season. The study area was visited weekly and leaf samples were collected at the adult phase of species. Taxonomic nomenclature was done according to Davis (1965, 1985) and Davis *et al.* (1988) and Latin names were updated following Brummitt and Powell (1992). Plant specimens were deposited in the Ondokuz Mayıs University Herbarium (OMUB). Percentage covers of plant species were also determined subjectwise in both plots. Multitudinous plant samples of each species were taken from both plots for repetition. The largest and fully expanded fresh leaves were used for calculation of leaf traits.

Fresh weight of leaves were measured by aid of Kern PLS 360-3 scales at the earliest after collection from the field. Rehydration procedure was not used because the study area was close to the laboratory. Leaves were put into drying oven at 70°C about 48 hrs until constant weight. When the weights of leave samples became stable, they were weighed again and their dry weight was determined. Percantage of dry matter content (DMC) of leaves was calculated as:

DMC% = Mean dry weight (mg) / Mean humid weight (mg) × 100.

Leaf area measurement software produced by University of Sheffield was used to determine the mean leaf areas of plants. SLA values of each species were calculated by using equation as mm^2/mg, mean leaf area (mm^2)/mean leaf dry weight (mg).

Plant species were grouped into four growth forms (trees > 4 m, shrubs <4 m, herbs and grasses) and also annual and perennial. Statistical analyses were conducted on four growth forms, annuals and perennials. Mean trait values were computed for each growth form and the variation in mean trait values among four growth forms, annuals and perennials were evaluated by an analysis of variance (one way - ANOVA). The Tukey post-hoc test was used to test for growth form differences with 0.01 and 0.05 levels of significance. Pearson correlation coefficients were carried out to determine any corelation among leaf traits. All statistical analyses were done using SPSS (15.0)

Results and Discussion

Leaf traits of 62 plant species (5 trees, 8 shrubs, 6 grasses and 43 herbs) recorded from 29 families in plot 1 and 50 plant species from 26 families (3 trees, 6 shrubs, 5 grasses and 36 herbs) in plot 2 were determined and evaluated. Dry weight, LDMC, leaf area, SLA, fresh weight of different growth forms in plots were measured (Fig. 1).

Results from ANOVA showed that dry matter content of leaves differed significantly among growth forms ($p < 0.01$) in plot 1 (Table 1). Considerably significant correlations were found between leaf traits (Table 2).

Table 1. ANOVA table of differences between growth forms in plot 1 and plot 2.

Plot 1	F-value	Sign.	Plot 2	F-value	Sign.
Fresh weight (mg)	0.245	0.864	Fresh weight (mg)	0.262	0.853
Dry weight (mg)	0.117	0.950	Dry weight (mg)	0.144	0.933
Dry matter content (%)	18.338	0.000**	Dry matter content (%)	19.934	0.000**
Leaf area (mm^2)	0.501	0.683	Leaf area (mm^2)	0.770	0.517
SLA (mm^2/mg)	2.658	0.057	SLA (mm^2/mg)	2.209	0.100

** Correlation is significant at the 0.01% level.

Table 2. Pearson correlation among leaf traits of different growth forms in plot 1 and plot 2 (DW: dry weight, LDMC: leaf dry matter content, LA: leaf area, SLA: spesific leaf area, FW: fresh weight).

	Plot 1	Plot 2		Plot 1	Plot 2
Trees			**Grasses**		
DW-LDMC	–0.866	–0.943	DW-LDMC	0.339	0.763
DW-LA	0.965**	0.983	DW-LA	0.491	0.968**
DW-SLA	–0.628	–1.000**	DW-SLA	–0.380	–0.193
DW-FW	1.000**	1.000**	DW-FW	0.817*	0.060
LDMC-LA	–0.878	–0.988	LDMC-LA	–0.415	0.786
LDMC-SLA	0.579	0.942	LDMC-SLA	–0.587	0.012
LDMC-FW	–0.864	–0.942	LDMC-FW	–0.241	–0.166
LA-SLA	–0.443	–0.983	LA-SLA	0.544	0.058
LA-FW	0.964**	0.983	LA-FW	0.844*	–0.086
SLA-FW	–0.620	–1.000**	SLA-FW	0.075	–0.562
Shrubs			**Herbs**		
DW-LDMC	0.386	–0.831*	DW-LDMC	0.520**	0.643**
DW-LA	0.952**	0.889*	DW-LA	0.770**	0.973**
DW-SLA	–0.317	0.653	DW-SLA	–0.333*	–0.318
DW-FW	0.975**	0.949**	DW-FW	0.924**	0.976**
LDMC-LA	0.185	–0.959**	LDMC-LA	0.218	0.559**
LDMC-SLA	–0.852**	–0.876*	LDMC-SLA	–0.393**	–0.275
LDMC-FW	0.203	–0.952**	LDMC-FW	0.351*	0.549**
LA-SLA	–0.074	0.916*	LA-SLA	–0.147	–0.304
LA-FW	0.985**	0.974**	LA-FW	0.953**	0.994**
SLA-FW	–0.139	0.807	SLA-FW	–0.257	–0.346

**Correlations are significant at 0.01 and 0.05% level, respectively.

Leaf traits of plant species were also examined according to annual and perennial plant species (Fig. 2). No significant differences were found between perennial (46) and annual (16) plant species in plot 1 (Table 3). In plot 2, there were significant differences between perennial (37) and annual (13) plant species in LDMC and SLA values.

Table 3. ANOVA table of differences between perennial and annual plant species in plot 1 and plot 2.

Plot 1	F	Sig.	Plot 2	F	Sig.
Dry matter	1.25	0.269	Dry matter	0.585	0.448
LDMC	1.13	0.291	LDMC	5.41	0.024 *
Leaf area	3.72	0.058	Leaf area	1.01	0.319
SLA	2.63	0.110	SLA	6.80	0.012 *
Fresh weight	2.31	0.134	Fresh weight	0.44	0.511

*Correlation is significant at the 0.05% level.

In both plots, growth forms significantly differ only in LDMC. Wilson *et al.* (1999) and Garnier *et al.* (2001) reported that due to diurnal variation of SLA, LDMC was more stable than SLA (Liu *et al.* 2008). Liu *et al.* (2008) reported that the differences in LDMC among species were larger than that of SLA. Duru *et al.* (2009) reported that, LDMC was the functional parameter that best describe the species for plant features useful to rank grassland communities for their herbage growth pattern. Values of LDMC were ranged from big to small as trees, grasses, shrubs and herbs in plot 1 and as trees, shrubs, grasses and herbs in plot 2. These differences between two plots may result from differences in canopy cover because of lumbering. So, in plot 1 light avability was more than plot 2. Differences in values of LDMC of growth forms between two plots were not significant. It was found that neither of these lumbering and harvesting factors are enough to change leaf traits of plants, or such as lumbering and harvesting type may not be effective on these plant traits.

The maximum SLA value was determined for herbs in both areas. White and Scott (2006) reported that SLA decreases with increased τ (relative intercepted light). It can be mentioned that SLA decreases with height, for example species belonging to the genus *Coprosma* tended to have higher SLA values indicative of its low light requirements due to its understory habit (White and Scott 2006). Smaller SLA values due to reduced leaf water content as a function of height is confirmed by evidence that stem hydraulic conductance of water decreases with height in tall forests (Ryan *et al.* 2000, White and Scott 2006).

There were significant correlations among leaf traits of growth forms. For trees and shrubs dry weight, leaf area and fresh weight strongly correlated each other and other leaf traits were important for leaf structure and photosynthetic capacity. SLA and dry matter content were not correlated with any leaf trait in trees. In shrubs, SLA and dry matter content were related only to each others. In the grassses, correlation among leaf traits is less significant compared to trees, shrubs and herbs. These findings are more or less supported by different literatures. A negative correlation was found between SLA and LDMC in several studies (Garnier *et al.* 2001, Shipley and Thi-Tam 2002, Wright *et al.* 2004, Wright *et al.* 2005, Liu *et al.* 2008). Similarly, in this study, negative correlations were found between SLA and LDMC for shrubs and herbs in plot 1 and only for shrubs in plot 2. In general, increased SLA is associated with decreased LDMC (Li *et al.* 2005). It was found that there was a positive correlation between leaf area and fresh weight for all growth forms in both areas. White and Scott (2006) reported that differences in SLA were linked to leaf water content for 34 herbaceous species (Shipley 1995). It had been shown that SLA reflected previously captured resources and indicated that species with high SLA exhibit high productivity (Poorter and Van der Werf 1998, Van der Werf *et al.* 1998, Wilson *et al.* 1999, Li *et al.* 2005). According to Luo *et al.* (2005), generally the relationships among leaf traits across diverse communities and ecosystems have significant implications for global-scale modeling of vegetation-atmosphere CO_2 exchange.

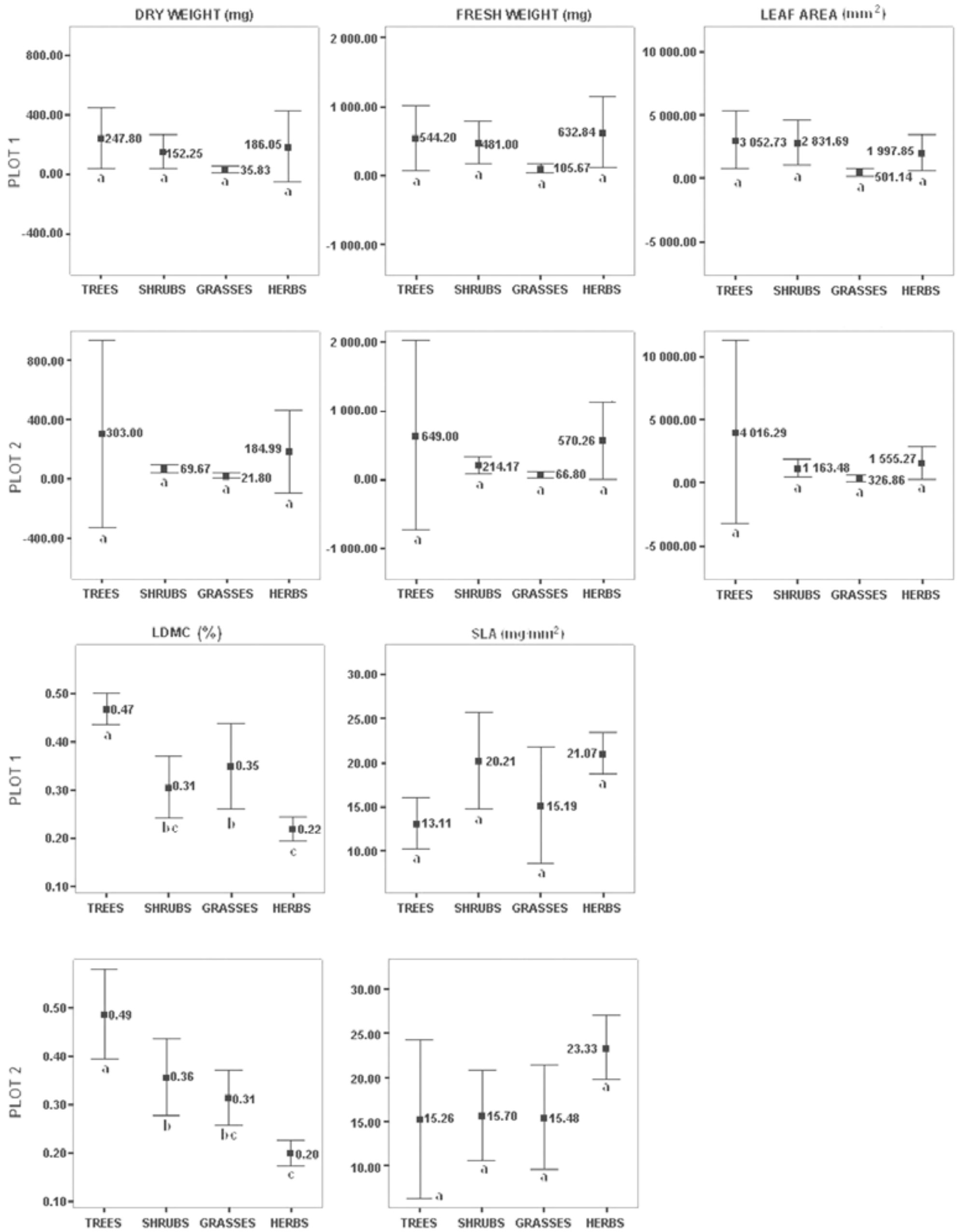

Fig. 1. Dry weight, fresh weight, LDMC, leaf area and SLA values of plants of growth forms in plots 1 and 2.

In our study, SLA of annual plant species was higher than those of selected perennial species in both plots. Li *et al.* (2005) also reported similar results. This finding is in consistent with results from laboratory experiments (Muller and Garnier 1990, Garnier 1992, Roumet *et al.* 1996) and a field studies (Garnier *et al.* 1997, Li *et al.* 2005). It may results from differences in anatomical

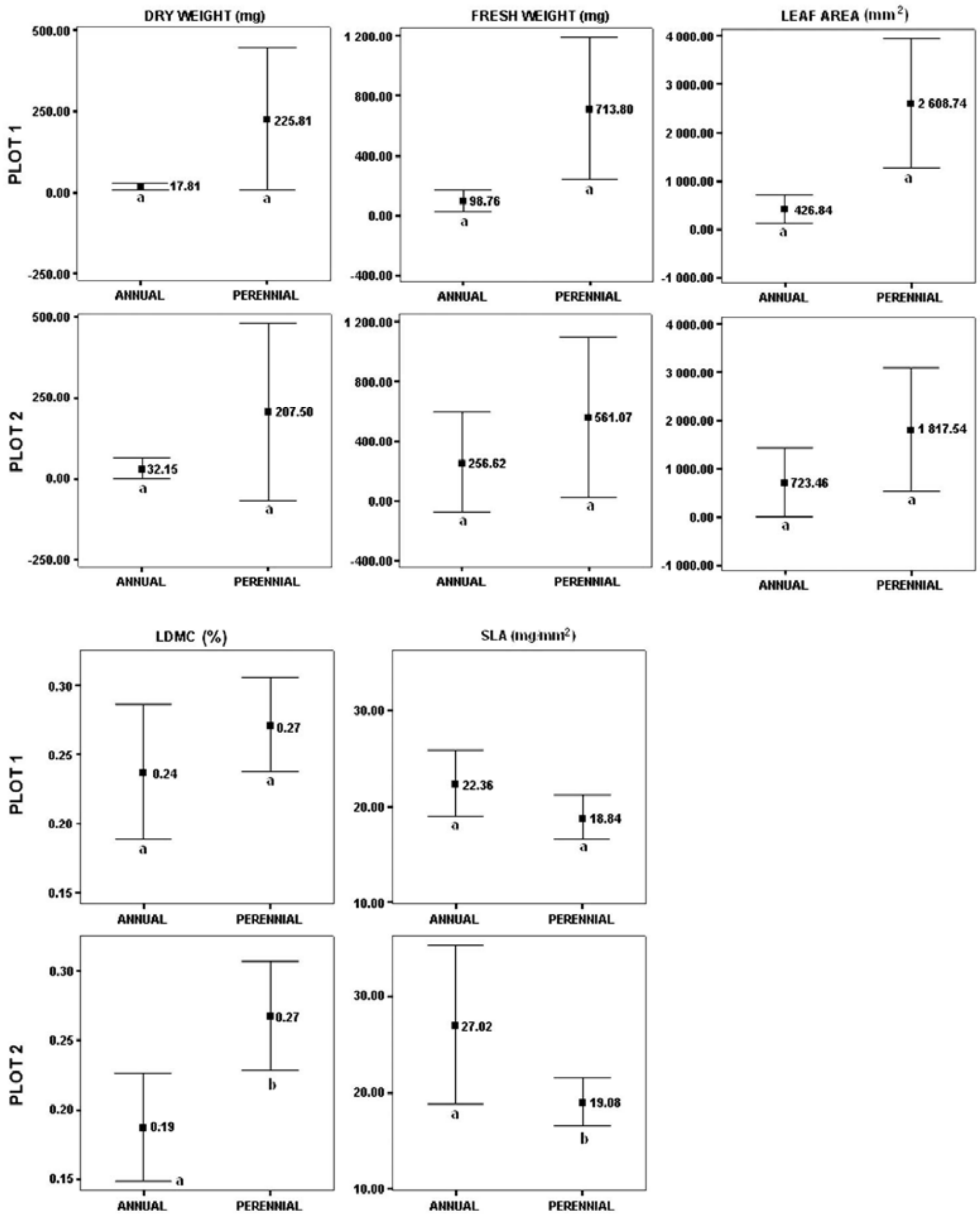

Fig. 2. Dry weight, fresh weight, LDMC, leaf area and SLA values of annual and perennial plant species in plots 1 and 2.

features. In the perennials, amount of dry matter per unit is higher than annuals because of higher proportion of ligneous tissues, water and also secondary growth. Differences in SLA and LDMC between annual and perennial species may also be related to other leaf traits such as leaf size (Shipley 1995, Li *et al.* 2005).

Determining effects of factors such as harvesting, lumbering, grazing etc. is important for land sustainability and management. In the current study, harvesting and lumbering were not found to be effective on leaf traits.

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